APPENDIX C. STATISTICAL TESTS AND MODELING TOOLS

STATISTICAL ANALYSES

In order to use parametric tests, (Student *t* test, ANOVA, MANOVA, etc.) assumptions about the population distribution must be made. When the data are not normally distributed, transformations of the data to obtain a normal distribution are commonly made (e.g., log transformation). Less powerful, non-parametric tests of significance must be used in cases where the data do not fit the assumption of a normal distribution (Atlas and Bartha 1993).

STUDENT *t* TEST

The validity of hypotheses is frequently tested using the Student *t* test. There is a family of distributions for the *t* statistic that vary as a function of degrees of freedom. The *t* distributions are symmetrical about a mean of 0, as are normal distributions, though the *t* distributions are more spread out than on the normal curve. As degrees of freedom increase, the *t* distribution more closely approximates the normal curve. There are published tables of critical values for *t* that allow one to compare a calculated *t* value from one's own data with a *t* value determined by the level of significance. This comparison allows one to decide whether or not to reject the null hypothesis (Atlas and Bartha 1993). An in-depth discussion of the use of the *t* statistic for analyzing environmental data can be found in Ott (1995). Most statistics texts include the published tables of the *t* statistic and information on it's application.

ANOVA

The analysis of variance (ANOVA) method is used to determine the significance or validity of data when information is collected from different populations. ANOVA is generally used to confirm that there are not significant differences in sample population means. ANOVA determines whether there is greater variability among sample populations or within population groups. ANOVA is performed by summing the variance of all sample points and comparing it to the sum of the variance of all the sample means (Remington and Schork 1985). ANOVA is useful for calculating the unbiased variance of samples that have been composited or parts of samples (such as a 10 mL water sample analyzed for TP taken from a 50 mL total sample) (Gilbert 1987).

CHI SQUARE TEST

A common non-parametric statistical test is the χ^2 (chi square) test. When attempting to analyze the apportionment of a characteristic within a population, the chi square test is valuable for determining the independence of categorical variables. The raw data for a chi square test should be on a scale for which data are placed into discrete groups (nominal scale) (Atlas and Bartha 1993).

MANN WHITNEY *U* TEST

The Mann Whitney *U* test is one of the most powerful non-parametric statistical tests. This test may be employed in place of the *t* test when data are on an ordinal scale. This test is used with two independent groups. The null hypothesis is that both samples are drawn from populations with the same distributions. The alternative hypothesis is that the parent populations from which the samples are taken have different medians. This test assumes that the distributions have the same form, but have different medians. This test ranks scores from lowest to highest while retaining the identity of the group from which they came (control or experimental group), to determine the distribution of the *U* statistic. *U* represents the number of times the n_1 value precedes the n_2 value. *U* is large if the n_1 population is located below the n_2 population.

LINEAR REGRESSION

In regression analysis a relationship of best fit is used to describe the data. The experimenter must decide the type of relationship that best describes the data. If the relationship is linear, a linear regression may be appropriate. When the data are not linear, they may be log transformed to fit the linear assumption. The slope of the regression line is called the regression coefficient. In constructing a regression line of best fit, it is necessary to define the slope of the line and the intercept of an axis. Regression analysis minimizes the variance, though a residual variance remains. The statistical significance of the regression coefficient using the student *t* test described above. The null hypothesis in such a test, is that there is no difference between the calculated regression coefficient and a true population regression coefficient 0. In other words, the population regression coefficient indicates that no prediction of *y* can be made from *x*, nor of *x* from *y* (Atlas and Bartha 1993).

MULTIPLE REGRESSION

Multiple regression is based on the same principle as linear regression (where y=mx+b), but involves more than one regression variable (i.e., multiple sets of *x* values). Multiple regression is often performed using matrices and least squares approximations (Myers 1990). Applications may include developing relationships between response variables for various indicators.

BAYESIAN ANALYSIS

Bayesian analysis is most useful when incorporating historical data or comparing probabilities of various competing hypotheses. It allows use of all available data from various studies and weighing of different outcomes. A discussion of the uses of Bayes Theorem in statistical analysis can be found in Hilborn and Mangel (1997).

MODELS

The models discussed in this appendix may be used in criteria derivation when data are not sufficient. However, only the WASP model predicts periphyton biomass. The other models described here use periphyton as a forcing function for predicting nutrients or DO.

BETTER ASSESSMENT SCIENCE INTEGRATING POINT AND NONPOINT SOURCES (BASINS)

Better Assessment Science Integrating Point and Nonpoint Sources, or BASINS, is a tool developed by EPA to facilitate water quality analysis on a watershed level and for specific waterbodies or stream segments. BASINS was designed to integrate national water quality data, modeling capabilities, and geographic information systems (GIS) so that regional, State, local and Tribal agencies can easily address the effects of both point and nonpoint source pollution and perform sophisticated environmental assessments.

BASINS is made up of five components: (1) national databases; (2) assessment tools (TARGET, ASSESS, and Data Mining) for evaluating water quality and point source loadings at a variety of scales; (3) utilities including local data import, land-use and DEM (Digital Elevation Model) reclassification, watershed delineation, and management of water quality observation data; (4) watershed and water quality models including NPSM (Nonpoint Source Model), HSPF (Hydrologic Simulation Program Fortan), TOXIROUTE, and QUAL2E; and (5) post processing output tools for interpreting model results.

The three analytical tools (TARGET, ASSESS, and Data Mining) within BASINS allow the user a range of environmental assessment options. TARGET examines large area watersheds on a State/Tribal or regional level to analyze point source loads or general water quality. ASSESS gives information about specific water bodies and the monitoring stations or discharge points near them. Data Mining integrates historical, geographic, and water quality data using maps and tables. In addition, models such as the NPSM, QUAL2E, and TOXIROUTE can be used to predict the fate, transport, and effects of loadings from various sources. The BASINS package can be used for many water quality management analyses, particularly the development of total maximum daily loads (TMDLs). In addition, the GIS component of BASINS allows the user to virtually traverse the watershed.

BASINS is a software package that is installed on the user's computer. It may be downloaded from the EPA website (http://www.epa.gov/ost/BASINS/download.htm) or ordered on CD-ROM from the National Service Center for Environmental Publications (NSCEP). A printed copy of BASINS version 2.0 Users' Manual is also available through NSCEP. BASINS training courses are available in some areas of the country. For more information on BASINS, see the BASINS website (http://www.epa.gov/ost/BASINS/).

HYDROLOGICAL SIMULATION PROGRAM - FORTRAN (HSPF)

HSPF is a comprehensive package developed by EPA for simulating water quantity and quality for a wide range of organic and inorganic pollutants from agricultural watersheds (Bicknell et al. 1993). The model uses continuous simulations of water balance and pollutant generation, transformation, and transport. Time series of the runoff flow rate, sediment yield, and user-specified pollutant concentrations can be generated at any point in the watershed. The model also includes instream quality components for nutrient fate and transport, biochemical oxygen demand (BOD), dissolved oxygen (DO), pH, phytoplankton, zooplankton, and benthic algae. Statistical features are incorporated into the model to allow for frequency-duration analysis of specific output parameters. Data requirements for HSPF are extensive, and calibration and verification are recommended. The program is maintained on IBM microcomputers and DEC/VAX systems. Because of its comprehensive nature, the HSPF model requires highly trained personnel. It is recommended that its application to real case studies be carried out as a team effort. The model has been extensively used for both screening-level and detailed analyses. Moore et al. (1992) describe an application to model BMP effects on a Tennessee watershed. Scheckenberger and Kennedy (1994) discuss how HSPF can be used in subwatershed planning. The HSPF model can be downloaded at EPA's BASINS website given above.

QUAL2E

The Enhanced Stream Water Quality Model (QUAL2E), originally developed in the early 1970s, is a one-dimensional water quality model that assumes steady-state flow but allows simulation of diurnal variations in temperature or algal photosynthesis and respiration (Brown and Barnwell 1987). QUAL2E represents the stream as a system of reaches of variable length, each of which is subdivided into computational elements that have the same length in all reaches. The basic equation used in QUAL2E is the one-dimensional advection-dispersion mass transport equation. An advantage of QUAL2E is that it includes components that allow quick implementation of uncertainty analysis using sensitivity analysis, first-order error analysis, or Monte Carlo simulation. The model has been widely used for stream waste load allocations and discharge permit determinations in the United States and other countries. EPA's Office of Science and Technology recently developed a Microsoft Windows-based interface for QUAL2E that facilitates data input and output evaluation, and QUAL2E is one of the models included in EPA’s BASINS tool. More information on QUAL2E, including downloadable program files, can be found at EPA’s website (www.epa.gov/docs/QUAL2E_WINDOWS/index.html).

CE-QUAL-RIV1

The one-dimensional Hydrodynamic and Water Quality Model for Streams (CE-QUAL-RIV1) was developed through the Waterways Experiment Station of the Corps of Engineers. The model was designed to simulate water quality conditions associated with the highly unsteady flows that can occur in regulated rivers (e.g., storm water flows and streams below peaking hydropower dams). The model has two submodels for hydrodynamics (RIV1H) and water quality (RIV1Q). Output from the hydrodynamic solution is used to drive the water quality model. Water quality constituents modeled include temperature, dissolved oxygen, carbonaceous biochemical oxygen demand, organic nitrogen, ammonia nitrogen, nitrate nitrogen, and soluble reactive phosphorus. The effects of algae and macrophytes on water quality can also be included as external forcing functions specified by the user. A limitation of CE-QUAL-RIV1 is that it is only applicable to situations where flow is predominantly one-dimensional. Currently, this model can only be downloaded for USCOE use. More information on CE-QUAL-RIV1 can be found at the WES website (www.wes.army.mil/el/elmodels/riveinfo.html).

CE-QUAL-W2

CE-QUAL-W2 is a two-dimensional, longitudinal/vertical water quality model that can be applied to most waterbody types. It includes both a hydrodynamic component (dealing with circulation, transport, and deposition) and a water quality component. The hydrodynamic and water quality routines are directly coupled, although the water quality routines can be updated less frequently than the hydrodynamic time step to reduce the computational burden in complex systems. Water quality constituents that can be modeled include algae, dissolved oxygen, ammonia-nitrogen, nitrate-nitrogen, phosphorus, total inorganic carbon, and pH. http://www.wes.army.mil/el/elmodels/w2info.html

WASP5

The Water Quality Analysis Simulation Program is a general-purpose modeling system for assessing the fate and transport of conventional and toxic pollutants in surface waterbodies. Its EUTRO5 submodel is designed to address eutrophication processes and has been used in a wide range of regulatory and water quality management applications. The model may be applied to most waterbodies in one, two, or three dimensions and can be used to predict time-varying concentrations of water quality constituents. The model reports a set of parameters, including dissolved oxygen concentration, carbonaceous biochemical oxygen demand (BOD), ultimate BOD, phytoplankton, carbon, chlorophyll *a*, TN, total inorganic nitrogen, ammonia, nitrate, organic nitrogen, total inorganic nitrogen, organic phosphorus, and inorganic phosphorus. Although zooplankton dynamics are not simulated in EUTRO5, their effect can be described by user-specified forcing functions. Lung and Larson (1995) used EUTRO5 to evaluate phosphorus loading reduction scenarios for the Upper Mississippi River and Lake Pepin, while Cockrum and Warwick (1994) used WASP to characterize the impact of agricultural activities on instream water quality in a periphyton-dominated stream. http://www.epa.gov/earth100/records/wasp.html